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1 Description

3 Optical Module And Optical System

5 The invention relates to an optical module having a circuit
6 carrier, an unpackaged semiconductor device flip-chip-mounted
7 on the circuit carrier, and a lens unit for projecting
8 electromagnetic radiation onto the semiconductor device, the
9 lens unit comprising a lens holder and a lens assembly with
10 at least one lens.

12 The invention further relates to an optical system having an
13 optical module implemented in this manner.

15 Generic optical modules and systems are used particularly in
16 automotive engineering.

18 In this area, electromagnetic radiation from various
19 frequency ranges can be used whereby, cumulatively to visible
20 light which is typically employed by applications on the
21 exterior of a motor vehicle such as lane departure warning
22 (LDW), blind spot detection (BSD) or rear view cameras,
23 particularly the infrared radiation invisible to humans is
24 preferred for applications in the interior of a motor
25 vehicle, such as out of position detection (OOP) or
26 additional exterior lighting of a night vision system.

28 Because of external effects such as temperature, humidity,
29 dirt and vibration, applications inside and outside a vehicle
30 are subject to exacting requirements. The typical service
31 life for in-vehicle systems is 10 to 15 years with only
32 extremely low failure rates being tolerated, so that

1 components of an optical system of the abovementioned type
2 must also exhibit only very slow aging.

3
4 As space for mounting optical modules or optical systems is
5 at a premium in many cases, additional difficulties exist for
6 implementing the optical systems. Using conventional means,
7 it is therefore extremely difficult to construct a reliable,
8 hermetically sealed unit comprising a camera chip (currently
9 CCD- or CMOS sensor) and associated optics.

10
11 For example, in systems of this kind which are used to record
12 images or information, it is acknowledged that the optics
13 must have their precise focal point at the point of
14 conversion from light to information (e.g. film level,
15 optical surface of CCD or CMOS sensor). The distance between
16 the camera chip and optical system must either be set and
17 fixed basically once during manufacture or the focal point is
18 re-set for each image (focusing on object, not fading rays).
19 This results in considerable manufacturing costs and also
20 poses a quality risk.

21
22 For cost and quality assurance reasons, however, cameras for
23 specific low cost application such as automotive, industrial,
24 digital camera, cell phone, toy, etc. must be manufacturable
25 as far as possible without adjustment processes between
26 optical system and camera chip, i.e. without setting the
27 focal point to the optical surface of the CMOS or CCD sensor.
28 This is fundamentally contrary to the abovementioned
29 requirements.

30
31 One possibility for developing a focus-free system is to
32 reduce the sum of the possible tolerances and devices so that
33 the module or system is designed to operate without

1 adjustment at least within a particular distance or
2 temperature range. If the invention is used e.g. as part of a
3 motor vehicle's occupant protection system (to which,
4 however, the present invention is not limited), sharp images
5 at distances of e.g. 15 to 130 cm and temperatures of e.g. -
6 40 to + 105°C must be ensurable. This is more readily
7 implementable the smaller the number of devices included in
8 the tolerance chain. The circuit carrier for the camera chip
9 (e.g. CCD or CMOS) constitutes a major portion of the
10 tolerance chain. Thus, for example, by using very thin, so-
11 called flexible printed boards it is attempted to introduce
12 only a small thickness tolerance. In addition, the necessary
13 soldered or in some cases glued joints between chip and
14 circuit carrier in particular account for a large portion of
15 the tolerance chain.

16
17 However, this solution, in particular the mounting of a
18 semiconductor device on a flexible printed board, also has
19 its disadvantages. For example, it makes handling such as
20 squeegeeing, component placement, soldering, separating, etc.
21 more difficult; the torsional stiffness and therefore the
22 process reliability is often worse than with so-called
23 printed circuit boards (PCBs), molded interconnect devices
24 (MIDs) or similarly implemented circuit carriers which,
25 however, make a considerable contribution to the tolerance
26 chain depending on their thickness dimensions. In addition,
27 there are disadvantages in terms of EMC behavior.

28
29 The object of the invention is to provide an optical module
30 and an optical system having an unpackaged semiconductor
31 device disposed on a circuit carrier, wherein the EMC
32 disadvantage is eliminated and/or the thickness tolerance of
33 the necessary circuit carrier is minimized as far as

1 possible, so that reliable optical quality can be provided
2 without adjustment and in particular focusing complexity and
3 maintained over the service life of the module or system
4 which can be easily and inexpensively assembled. Lastly,
5 particular measures shall guarantee process-safe fabrication
6 with ease of handling.

7
8 This object is achieved by the features set forth in the
9 independent claims. Advantageous embodiments of the
10 invention, which can be used individually or in combination
11 with one another, are set forth in the dependent claims.

12
13 The invention is based on the generic optical module in that
14 the circuit carrier itself has at least one thin region and a
15 thick region supporting the thin, relatively sensitive
16 region. Due to the spatial closeness of a thick region, a
17 circuit construction of this kind has advantages over a pure
18 flex solution in terms of EMC behavior. In addition, it
19 advantageously combines a minimized tolerance dimension with
20 greatly increased torsional stiffness.

21
22 According to the invention, the lens holder is preferably
23 disposed in a supported manner in the thin region of the
24 circuit carrier so as to ensure a defined reference dimension
25 between the lens holder or lens unit and the circuit carrier.

26
27 According to the invention, the semiconductor device is also
28 preferably disposed in or adjacent to a thin region of the
29 circuit carrier, thereby allowing a manufacturing technology
30 with ease of handling and ensuring particularly tight
31 tolerances between the semiconductor device, or more
32 precisely camera chip, and the lens unit. The thin region of
33 the circuit carrier is advantageously supported by the thick

1 region. This allows the semiconductor device to be mounted
2 (e.g. soldered, glued or similar) e.g. by means of flip-chip
3 technology on a thin but relatively stable, torsionally stiff
4 level plane, thereby advantageously ensuring process-safer
5 manufacturing than in the case of comparable processes for
6 mounting components on exclusively flexibly implemented
7 circuit carriers.

8
9 According to the invention, the thick region is preferably
10 made U-shaped in order to adequately support the thin region.
11 In an alternative embodiment, however, the thin, relatively
12 sensitive region is preferably supported in a clamped manner,
13 as in a frame, by a surrounding thick region. Other
14 embodiments are conceivable, as long as they support or clamp
15 the thin region, such as L-shaped, partially U-shaped, F- or
16 E-forked or similarly implemented thick regions.

17
18 The thick region is preferably rigidly implemented, e.g. as a
19 multilayer FR-4 printed circuit board (PCB) or the like.

20
21 Particularly for these materials, an appropriate solution is
22 to implement the thin first region of the circuit carrier by
23 recessing or milling out.

24
25 In an alternative development of the invention, the thin and
26 thick regions are implemented as a molded interconnect device
27 (MID) with integrated conductor tracks. MID technology is
28 essentially based on the use of hightemperature
29 thermoplastics which are metallized to form circuit
30 patterns. MIDs, i.e. 3-dimensional injection-molded circuit
31 carriers, are molded parts with integrated conductor
32 patterns. Attention is drawn particularly to the
33 rationalization potential of MID patterns, in which context

1 mention should also be made of the environmental
2 compatibility achieved compared to conventional circuit
3 carriers. MIDs can be produced in various ways, such as
4 fabricating the circuit carrier by one-shot injection
5 molding, metallization then taking place by means of hot-
6 embossing and the pattern then being created by mold
7 stamping. Likewise, one-shot injection molding can be
8 followed by metallization by electroplating. Following
9 metallization, whether it be by hot-embossing or
10 electroplating, a pattern can be also be created by 3D-
11 masking or an imaging laser process. The inventive circuit
12 carrier having at least two regions can also be fabricated
13 by other plastic-processing methods, such as two-shot
14 injection molding, for example. The metallization and
15 patterning of the MID can also be performed in an integrated
16 manner by means of a conductor pattern foil. The
17 abovementioned methods for manufacturing MIDs should only be
18 taken as examples of a number of known prior art methods,
19 MIDs manufactured in whatever manner being able to be used
20 within the scope of the present invention.

21
22 According to the invention the thin region is preferably
23 implemented as a flexible PCB or similar and the thick
24 region as a rigid PCB or similar. By means of the preferred
25 implementation of the thin region as a flexible printed
26 board or so-called flex foil, this meets all the
27 requirements that a circuit carrier supporting the
28 semiconductor device must satisfy within the scope of the
29 present invention, namely little or no creation of
30 additional uncertainties in respect of the optical design,
31 for which reason in particular flexible circuit boards with
32 as tight tolerances as possible must be used.

1 Relating specifically to the present invention, the
2 abovementioned embodiments of a first and second region of
3 the circuit carrier offer in approximately equal measure the
4 possibility of using a manufacturing technology with
5 particularly low tolerances between the semiconductor device
6 and lens unit disposed in or adjacent to the thin region of
7 the circuit carrier. The tolerance chain which in the case
8 of conventional designs is extended still further by the
9 thickness of the circuit carrier and the thickness of any
10 stabilizing devices provided, is advantageously reduced to a
11 minimum within the scope of the present invention.

12
13 According to the invention there are preferably implemented
14 on the lens holder, at least partially, support elements via
15 which the lens holder and therefore the lens unit bear a
16 relationship to the circuit carrier in a defined dimension
17 with respect to the optical system. The lens unit and
18 circuit carrier are interconnected in an otherwise normal
19 manner, preferably adjacently to the support elements,
20 specifically glued, laser-welded, screwed, riveted or
21 similar, a connection thereby being provided by means of the
22 standoffs between circuit board and lens holder or lens
23 unit, which connection causes no additional uncertainty in
24 respect of the optical quality of the module.

25
26 In an alternative embodiment of the present invention, the
27 thick second region of the circuit carrier is part of the
28 lens unit or, more precisely, of the lens holder, said lens
29 holder preferably being implemented as an MID (molded
30 interconnect device) with integrated conductor tracks. In
31 this way the number of components required is again reduced -
32 while retaining the inventive supporting of the thin region.
33 Due to the fact that, if the lens holder is implemented as an

1 MID, conductor tracks are incorporated, the semiconductor
2 device can be directly soldered or glued adjacently to or
3 into the thin region of the lens holder. And even if the
4 first thin region is implemented by means of flex-foil, a
5 manufacturing technology with particularly tight tolerances
6 between the semiconductor device and the lens unit is
7 provided. In addition, the supporting according to the
8 invention results in a relatively stable, planar thin region,
9 which makes component placement, mounting or the like
10 particularly easy.

11
12 The semiconductor device is preferably disposed on the side
13 of the circuit carrier facing away from the lens unit, the
14 thin region in the circuit carrier having an opening through
15 which electromagnetic radiation is projected by the lens
16 assembly onto the semiconductor device. The optical module is
17 therefore constructed in the following sequence: lens
18 assembly/circuit carrier (or more precisely flexible printed
19 board)/semiconductor device. Even if embodiments are
20 conceivable in which the order of circuit carrier and
21 semiconductor device is reversed, it has been found
22 particularly advantageous for the circuit carrier to be
23 provided with an opening, thereby allowing the first-
24 mentioned sequence.

25
26 The invention additionally consists of an optical system with
27 an optical module of the above kind. In this way the
28 advantages of the optical module also emerge as part of an
29 overall system.

30
31 The invention is based on the recognition that it is possible
32 to provide a compact, highly integrated module solution with
33 minimal dimensional variations which avoids the

1 abovementioned prior art disadvantages and, in particular,
2 can be manufactured in a more process-safe manner, can be
3 mounted more easily and is consequently particularly
4 inexpensive.

5
6 It succeeds in providing various functionalities while
7 simultaneously minimizing dimensions.

8
9 The optical module and the optical system are virtually
10 maintenance-free. Also particularly relevant to cost savings
11 is the fact that no optical adjustment of the optical module
12 is required, as this is now better provided by the
13 geometrical configuration of the components and as the
14 tolerance chain is shortened by minimizing the circuit
15 carrier tolerance to one dimension while at the same time
16 improving handling in production engineering terms.

17
18 The module is stable and of high quality; moreover, an
19 integrated modular solution for sensor and optical system is
20 provided. This modularity means that the number of variants
21 is reduced, which is consonant with the interchangeable part
22 concept constantly striven for.

23
24 All in all, an integrated solution comprising sensor and
25 optical system as well as possibly lighting and/or heating
26 equipment is provided which uses a particularly inexpensive
27 connection between optical module and main board.

28
29 The invention can be particularly usefully employed for
30 implementing video systems, possibly in combination with
31 radar systems, ultrasonic systems or the like in the
32 automotive field.

1 The invention will now be explained using examples with
2 reference to the accompanying drawings based on preferred
3 embodiments:

4
5 Fig. 1 shows a first perspective view of an optical module
6 according to the invention;

7
8 Fig. 2 shows a second perspective view of an optical
9 module according to the invention;

10
11 Fig. 3 shows a third perspective, partially sectional view
12 of an optical module according to the invention;

13
14 Fig. 4 shows a first embodiment of a circuit carrier of
15 the module according to the invention, comprising a
16 thin region and a frame-shaped thick region;

17
18 Fig. 5 shows a second embodiment of a circuit carrier of
19 the module according to the invention, comprising a
20 thin region and a U-shaped thick region;

21
22 Fig. 6 shows an exploded perspective view of an optical
23 module according to the invention;

24
25 Fig. 7 shows a first sectional view of an optical module
26 according to the invention;

27
28 Fig. 8 shows a first lens holder of an optical module
29 according to the invention with partially
30 implemented support elements;

31

Fig. 9 shows a second lens holder of an optical module according to the invention with alternatively partially implemented support elements;

Fig. 10 shows a third lens holder of an optical module according to the invention with a circumferential support ring;

Fig. 11 shows a second side view of an optical module with a lens holder according to Fig. 10; and

Fig. 12 shows a third side view of an optical module according to the invention.

In the following description of the preferred embodiments of the present invention, the same reference numerals are used to denote identical or comparable components.

Fig. 1 shows a perspective view of an optical module according to the invention. In the assembled state of the optical module shown are a lens holder 14 and a circuit carrier 10 comprising a first thin region 10a and a second thick region 10b. Under the also recognizable glob top 26 there is disposed a light-sensitive semiconductor device (not shown) which is installed here as a flip-chip 12, which has the advantage that no additional tolerances are added within the sensor or component (e.g. carrier chip, adhesive, etc.). The opposite end of the thin region 10a of the circuit carrier 10 is provided with solder pads 28, so that a contact can be established between the optical module and a rigid circuit board (not shown), e.g. by hot-bar soldering using the solder pads 28, without having to provide an additional electrical connection. Alternatively, depending

1 on the design of the circuit carrier 10 and/or expediency,
2 an appropriate electrical connection can also be implemented
3 by a ribbon cable 36, as shown e.g. in Fig. 2. The side of
4 the optical module opposite the glob top 26 is provided with
5 cutouts and light emitting diodes 38 disposed therein.

6
7 Fig. 2 is a second perspective view of an optical module
8 according to the invention, showing a special alternating
9 arrangement of the light emitting diodes 38 around a lens 20
10 provided for the admission of radiation.

11
12 Fig. 3 is a perspective, partially sectional view of an
13 optical module according to the invention, showing the
14 interior of the lens holder 14. For the description of this
15 arrangement, reference is simultaneously made to Fig. 6
16 which contains an exploded view of the optical module
17 according to the invention, and to Fig. 7 which shows the
18 optical module in side elevation but with a lens assembly
19 16, 18, 20 enlarged to include a diaphragm 21 .

20
21 In the lens holder 14 according to Fig. 3, three lenses 16,
22 18, 20 are inserted. The lenses 16, 18, 20 and the diaphragm
23 21 shown in Fig. 7 are shaped in such a way that they assume
24 a defined position relative to one another inside the lens
25 holder 14. In addition, one of the lenses is so designed
26 that it interacts with the lens holder 14, thereby also
27 adopting a defined position with respect to the lens holder
28 14 and ultimately to the semiconductor device 12. In this
29 way all the lenses 16, 18, 20 are adjusted with respect to
30 the semiconductor device 12. This adjustment is unaffected
31 by other measures, as the lens holder 14 is disposed
32 directly in the thin region 10a of the circuit carrier on
33 top of same.

1
2 The connection between the semiconductor device 12 and the
3 circuit carrier 10a is established using a flip-chip
4 technique by creating a soldered joint via solder bumps 30.
5 The joint can then be strengthened with an underfill. To
6 ensure that electromagnetic radiation can pass from the lens
7 assembly 16, 18, 20; 21 disposed on the side facing away
8 from the populated surface of the circuit carrier 10 to the
9 semiconductor device 12, the thin region 10a has an opening
10 24. Through this opening 24, electromagnetic radiation can
11 reach an electromagnetic radiation sensitive surface 34 of
12 the semiconductor device 12.

13
14 The semiconductor device 12 can - according to present day
15 technology - be designed as CMOS or CCD. In addition to or
16 alongside the soldered joint 30, an adhesive bond can also
17 be provided. An underfill (not shown) can be applied for
18 strengthening. In order to protect the expensive
19 semiconductor device 12 against environmental effects and/or
20 unwanted light radiation from behind, a glob top 26 is
21 provided. In order to allow ventilation of the optical
22 module in the event of in particular severe temperature
23 fluctuations, a ventilation opening can be provided. It is
24 likewise possible to dispose an adhesive pressure
25 compensation seal (PCS) on an opening (not shown).

26
27 According to the invention, the optical module has a
28 specially implemented circuit carrier 10, comprising a thin
29 region 10a and a thick region 10b supporting the thin,
30 relatively sensitive region 10a as in a frame, the thin
31 region 10a preferably carrying a semiconductor device 12.

32

1 Fig. 4 shows a first embodiment of a circuit carrier 10 of
2 the module according to the invention, comprising a thin
3 region 10a and a frame-shaped thick region 10b.

4
5 Fig. 5 shows a second embodiment of a circuit carrier 10 of
6 the module according to the invention, comprising a thin
7 region 10a and a U-shaped thick region 10b.

8
9 It is clearly discernible how the thin region 10a is
10 advantageously supported by the U-shaped and frame-shaped
11 thick region 10b respectively.

12
13 Fig. 6 shows an exploded perspective view of the optical
14 module according to the invention including the light
15 emitting diodes 38, the alternating arrangement being clearly
16 illustrated in Fig. 6.

17
18 Fig. 7 shows an optical module with a lens unit, comprising a
19 lens holder 14 into which a lens assembly consisting e.g. of
20 three lenses 16, 18, 20 and a diaphragm 21 is inserted. The
21 lenses 16, 18, 20 and the diaphragm 21 are preferably
22 unambiguously oriented to one another and relative to the
23 lens holder 14 by their geometrical configuration, so that
24 no further optical adjustment of the system is required. The
25 thick region 10b of the circuit carrier 10 supports a first
26 region 10a, e.g. a flex foil, which carries an
27 electromagnetic radiation sensitive semiconductor device 12.
28 As the lens holder 14 in the thin region 10a of the circuit
29 board 10, which at the most has a very small tolerance, is
30 connected to the circuit carrier 10 e.g. via a screwed or
31 adhesive connection or the like, the semiconductor device 12
32 is also positioned in a defined manner relative to the other
33 optical devices, i.e. in particular the lenses 16, 18, 20.

1 Guide devices and/or bores 32 or the like implemented e.g.
2 on the lens holder 14 finally facilitate precise positioning
3 of circuit carrier 10 to lens unit 14 or vice versa.

4
5 For implementing the thick 10b region and the thin region
6 10a various designs are conceivable, in particular rigid and
7 flexible PCB, multilayer FR4 and thin PCB, milling out to a
8 precise dimension, implementation in MID or the like. In all
9 cases, the thin, relatively sensitive region 10a is
10 supported or clamped by the at least partially surrounding
11 relatively rigid region 10b as in a frame. The low tolerance
12 between PCB top- and underside are achieved by the thin
13 region 10a of the circuit carrier, possibly in combination
14 with additional measures such as matched lens systems, etc.

15
16 Contact between lens holder 14 and circuit carrier 10 is
17 established in the thin region 10a. In this connection,
18 Figs. 8 and 9 show a lens holder with partial supports 39.

19
20 Fig. 10 shows a lens holder 14 with a circumferential support
21 ring 39 which simultaneously seals the lens unit 14; 16, 18,
22 20; 21 to the circuit carrier 10 and vice versa in an
23 advantageous manner. This is shown in Fig. 11 in a sectional
24 view.

25
26 Fig. 12 lastly shows a circuit carrier 10 implemented
27 according to the invention with a recess 10a in the direction
28 of the flip-chip 12. In this embodiment, advantageously no
29 support elements need to be implemented on the lens holder
30 14. A circuit carrier 10 of this kind also provides improved
31 EMC behavior.

1 The present invention advantageously allows flip-chip devices
2 12 to be mounted to a thin, stably supported flat plane 10a.
3 In addition to easy panel processing, they also enable in
4 particular several layers around the flip-chip to be used,
5 e.g. FR4 layers, which has a positive effect on
6 electromagnetic compatibility (EMC) and on so-called routing.
7 It also advantageously allows integration of flip-chip
8 carriers and electronics unit on a single circuit carrier 10.

9
10 The features of the invention disclosed in the above
11 description, in the drawings and in the claims can be
12 essential to the implementation of the invention both
13 individually and in any combination. It is particularly
14 suitable for applications in the interior and/or exterior of
15 a motor vehicle.

16

17